AD-A124 979 TEMPERATURE CORRECTIONS FOR PO2 PCO2 AND PH IN GOAT BLOOD(U) ARMY RESEARCH INST OF ENVIRONMENTAL MEDICINE NATICK MA R A GABEL ET AL. 04 JAN 83 USARIEM-M4/83 1/1

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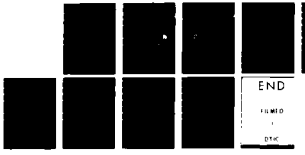

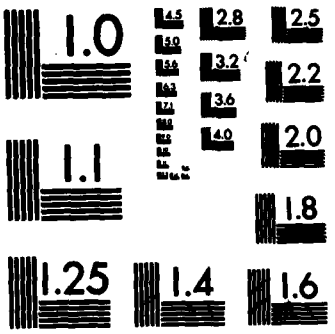

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Values for PO_2, PCO_2, and pH of blood in a closed system change with alterations in temperature. We carried out this investigation because equations were not available for making appropriate temperature corrections for goat blood. Fifty-eight samples of venous blood from ten goats were equilibrated at 40°C with gases giving a wide range of values of PO_2 and PCO_2. Each sample was simultaneously analyzed for these variables and for pH in two identical blood-gas analyzeers, one with electrodes maintained at 37°C, the other at 40°C. Values measured at 37°C were corrected

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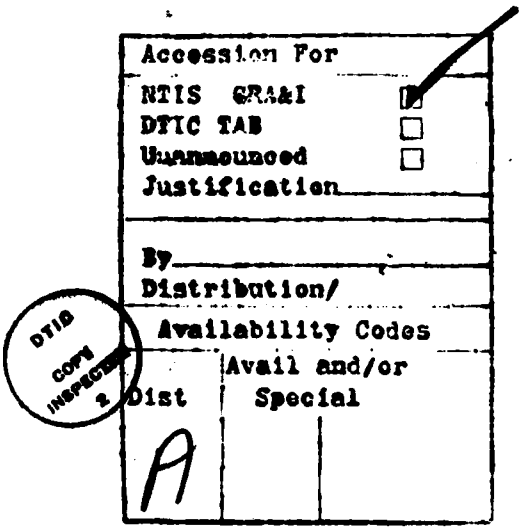
ANIMAL RESEARCH

In conducting the research described in this report, the investigators adhered to the "Guide for the Care and Use of Laboratory Animals," as prepared by the Committee on Care and Use of Laboratory Animals of the Institute of Laboratory Animal Resources, National Research Council.

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation.



21 Dec 1982

Temperature Corrections for PO_2, PCO_2, and pH in Goat Blood

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ABSTRACT

Values for PO_2, PCO_2, and pH of blood in a closed system change with alterations in temperature. We carried out this investigation because equations were not available for making appropriate temperature corrections for goat blood. Fifty-eight samples of venous blood from ten goats were equilibrated at 40°C with gases giving a wide range of values of PO_2 and PCO_2. Each sample was simultaneously analyzed for these variables and for pH in two identical blood-gas analyzers, one with electrodes maintained at 37°C, the other at 40°C. Values measured at 37°C were corrected to 40°C using equations developed to correct PO_2, PCO_2, and pH in human blood for changes in temperature. Values corrected to 40°C from 37°C were not significantly different from those measured directly at 40°C. Therefore, equations for correcting PO_2, PCO_2, and pH for temperature in human blood can be applied with confidence to goat blood within the range of temperatures studied.

Index Terms: Acid-Base Balance

Blood Gases

INTRODUCTION

Values of PO_2, PCO_2, and pH in blood not exposed to a gas phase vary with changes in temperature. Analysis of these variables would ideally be carried out with electrodes maintained at the temperature of the blood in vivo. Because this is usually not convenient, equations are used to correct measured values of PO_2, PCO_2, and pH for changes in temperature.

Studies we recently performed in goats required particularly accurate determination of PCO_2 in arterial blood in vivo. We knew of no experimentally verified algorithms for correcting values of PO_2, PCO_2, and pH in goat blood for differences in temperature between the goat's body and the analyzing electrodes. Therefore, we carried out this investigation to determine whether empirically derived equations for making these corrections for human blood are valid when applied to goat blood.

METHODS

Twenty to 80 ml of venous blood were withdrawn from each of ten goats (Capra hircus). The aliquots were divided into 58 5-ml samples, each of which was equilibrated at 40°C (Dynex Large Bubble Tonometer, Analytical Products, Inc.) for 20 min with a gas having PO_2 38-122 torr and PCO_2 22-99 torr. (An exception was

that 9 of the samples were equilibrated with a gas having PO_2 greater than 650 torr. PO_2 was not measured in these samples, because it would have been outside the range under study.) Base excess was not experimentally altered; measured values of pH varied because of experimentally induced changes in PCO_2 and preexisting differences in base excess.

Values of PO_2, PCO_2, and pH in each sample were measured simultaneously in two identical blood gas analyzers (BMS-3 MK2, Radiometer A/S), one with electrodes maintained at 37°C, the other at 40°C. Temperatures of the water baths were confirmed with a quartz calibrating thermometer (Hewlett-Packard Model 2804A). The PO_2 and PCO_2 electrodes of both analyzers were calibrated with the same set of gas standards, humidified to saturation at temperature of the electrodes. The pH electrodes were calibrated with precision buffers (Radiometer) having known values of pH at 37 and 40°C.

Each set of analyses (PO_2, PCO_2, and pH) was performed in triplicate. When one of the three measurements differed by more than 2 torr for PO_2, 1.5 torr for PCO_2, or 0.010 for pH, a fourth (and rarely a fifth) measurement was made. The arithmetic mean of three compatible measurements was taken as the measured

value. Values measured at $37^{o}C$ were then corrected to $40^{o}C$ using the following algorithms that compensate for changes in the temperature of human blood in a closed system (3,5,6):

$$Pc = Pm\ (\exp_{10}\ ((Tc-Tm)(0.0265/((Pm/146)^{3}+1) + 0.0007/(0.02\ (Pm-230)^{2}+1) + 0.0047))) \quad (1)$$

$$PPc = PPm\ (\exp_{10}\ (0.019\ (Tc-Tm))) \quad (2)$$

$$pHc = pHm - (Tc-Tm)(0.0146 + 0.0065\ (pHm-7.4)) \quad (3)$$

where Pc, PPc, and pHc are PO_2, PCO_2, and pH, respectively, corrected to Tc degrees Celsius, and Pm, PPm, and pHm are PO_2, PCO_2, and pH, respectively, measured at Tm degrees Celsius.

Data pairs were excluded (because of presumed measurement errors) if differences between measured and calculated values were farther than 3 standard deviations from the mean difference between all measured and corrected values. The numbers of pairs thus excluded were: PO_2: 2 of 49; PCO_2: 1 of 58; pH: 2 of 58.

Statistical analysis was performed using Student's t test and linear regression. In fitting straight lines to plots of measured versus corrected values, diagonal distances (as opposed to vertical) were minimized, because measurement errors were possible in abscissas as well as in ordinates (2).

RESULTS

Values of PO_2, PCO_2, and pH corrected to 40°C from 37°C were not significantly different (P greater than 0.08 by paired t test) from those measured directly at 40°C. That is, mean differences between corrected and directly measured values for each of the three variables did not significantly differ from zero. The differences were normally distributed around zero (Figures 1-3 top panels).

Figures 1-3

For each of the three variables, when corrected values (ordinates) were plotted against directly measured values (abscissas), the linear regression had a correlation coefficient of 0.999 or greater, a slope not significantly different from one (P greater than 0.34), and an x and a y intercept not significantly different from zero (that is, zero was within the 95 percent confidence limits for both x and y intercepts) (Figures 1-3 bottom panels).

DISCUSSION

PO_2 of blood in a closed system changes when the temperature is varied because of alterations in the affinity between oxygen and hemoglobin, in the solubility of oxygen in blood, and thus in the degree of saturation of hemoglobin with oxygen. Temperature has not only a direct effect on the affinity between oxygen and hemoglobin, but also an indirect effect produced through temperature-induced

changes in PCO_2 and pH, which also influence oxygen-hemoglobin affinity (3,6). PCO_2 and pH vary with temperature owing to changes in ionization constants of water and of ionizable solutes, as well as changes in the solubility of carbon dioxide in blood (3,6). Because of known differences between goat and human blood (1), there was reason to doubt that equations developed for human blood could be applied without modification to goat blood. However, within the range of temperatures studied, we found that equations for correcting PO_2, PCO_2, and pH in human blood for temperature can be applied with confidence to goat blood.

ACKNOWLEDGMENTS

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In conducting the research described in this report, the investigators adhered to the "Guide for the Care and Use of Laboratory Animals" as prepared by the Committee on Care and Use of Laboratory Animals of the Institute of Laboratory Animal Resources, National Research Council.

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REFERENCES

1. Altman, P.L., and D.S. Dittmer (Ed). Blood and Other Body Fluids. Washington: Federation of American Societies for Experimental Biology, 1961, p.116.

2. Brace, R.A. Fitting straight lines to experimental data. Am. J. Physiol. 233: R94-R99, 1977.

3. Gabel, R.A. Algorithms for calculating and correcting blood-gas and acid-base variables. Respir. Physiol. 42:211-232, 1980.

4. Lilliefors, H.W. On the Kolmogorov-Smirnov test for normality with mean and variance unknown. J. Am. Stat. Assoc. 62:399-402, 1967.

5. Ruiz, B.C., W.K. Tucker, and R.R. Kirby. A program for calculation of intrapulmonary shunts, blood-gas and acid-base values with a programmable calculator. Anesthesiology 42:88-95, 1975.

6. Severinghaus, J.W. Blood gas calculator. J. Appl. Physiol. 21:1108-1116, 1966.

LEGENDS FOR FIGURES

Figure 1

Top Panel: Frequencies of occurrence of differences between values corrected to 40°C from 37°C and those directly measured at 40°C are normally distributed around zero (P greater than 0.05 by Lilliefors test (4)). Positive differences indicate measured values greater than corrected. The mean difference is not significantly different from zero.

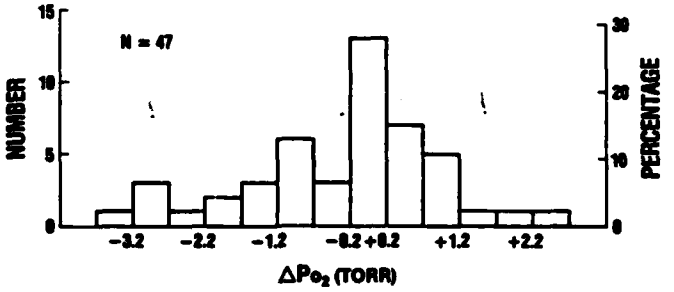
Bottom Panel: Linear regression (with 95 percent confidence limits) of values corrected to 40°C from 37°C versus those directly measured at 40°C. The slope is not significantly different from one, and the x and y intercepts are not significantly different from zero.

Figure 2

(See Figure 1 for legend.)

Figure 3

(See Figure 1 for legend.)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30
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−2.2
−1.2
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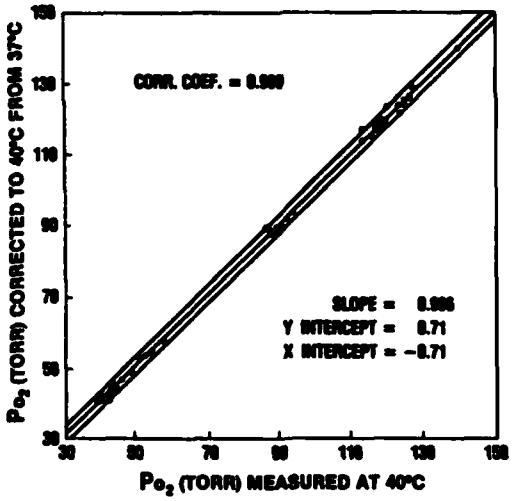
+1.2
+2.2
ΔPo2 (TORR)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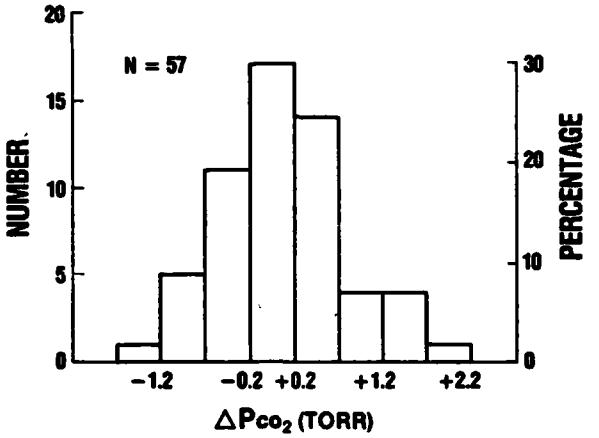
SLOPE = 0.986
Y INTERCEPT = 0.71
X INTERCEPT = −0.71
Po2 (TORR) CORRECTED TO 40°C FROM 37°C
Po2 (TORR) MEASURED AT 40°C

Figure 1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+1.2
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ΔPco2 (TORR)

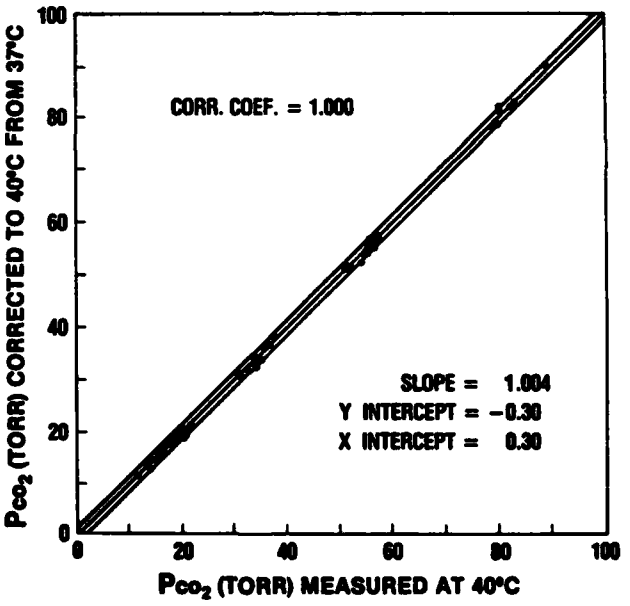
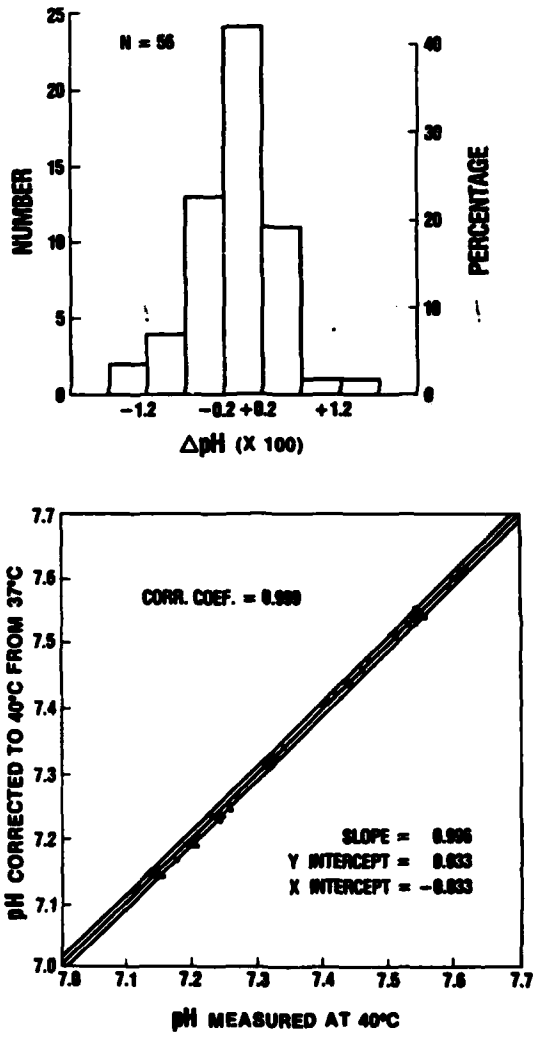

CORR. COEF. = 1.000
SLOPE = 1.004
Y INTERCEPT = −0.30
X INTERCEPT = 0.30
Pco2 (TORR) CORRECTED TO 40°C FROM 37°C
Pco2 (TORR) MEASURED AT 40°C
100
80
60
40
20
0
0
20
40
60
80
100

Figure 2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NUMBER
PERCENTAGE
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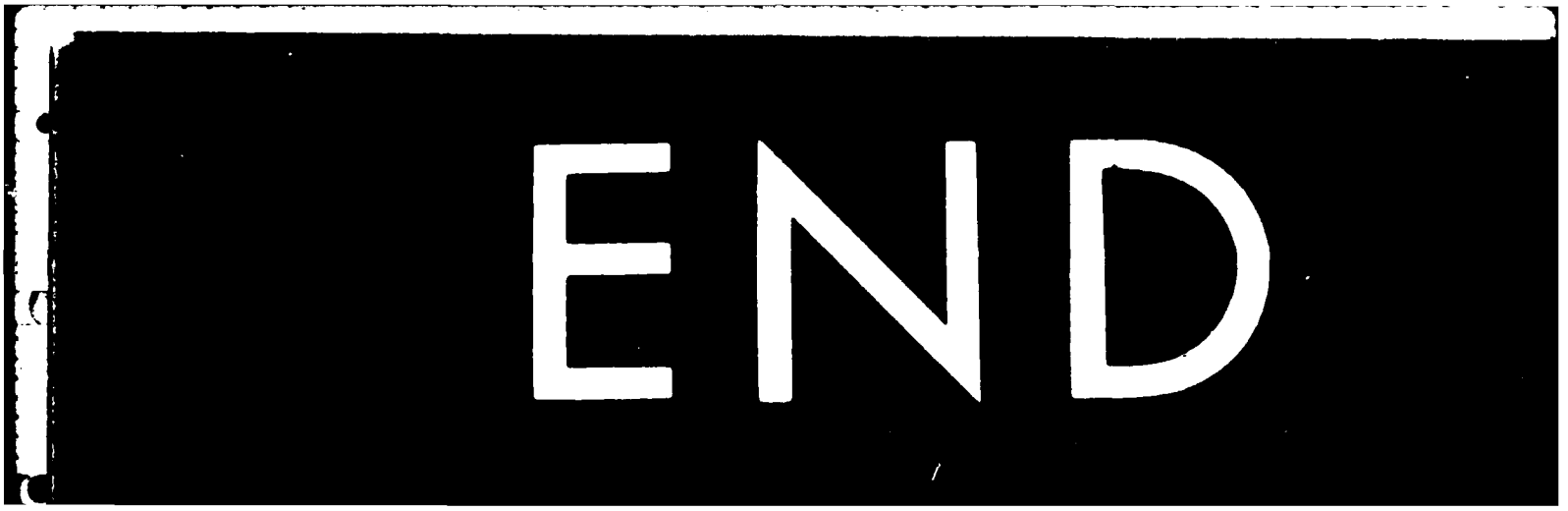
20
15
10
5
0
40
30
20
10
0
−1.2
−0.2 +0.2
+1.2
ΔpH (X 100)
CORR. COEF. = 0.999
SLOPE = 0.996
Y INTERCEPT = 0.033
X INTERCEPT = −0.033
pH CORRECTED TO 40°C FROM 37°C
pH MEASURED AT 40°C
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7.0
7.0
7.1
7.2
7.3
7.4
7.5
7.6
7.7

Figure 3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